Assessing Aerosol Data Assimilation Products Using DIAL/HSRL Measurements

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Ozone DIAL/HSRL System

Ozone Differential Absorption Lidar (DIAL)

and   NASA SEAC4RS

Aerosol/Cloud High Spectral Resolution Lidar (HSRL)

NASA DC-8

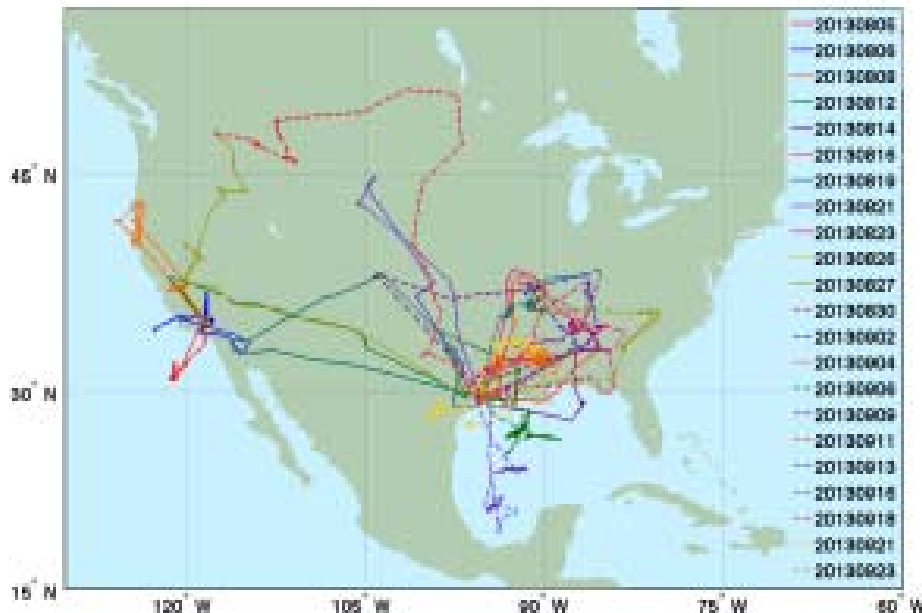SEAC[4]RS Field Mission

Instrument Summary

Simultaneous Nadir & Zenith measurements

Aerosol/Cloud 355, 532 (HSRL), 1064 nm
Nominal resolutions:
Extinction: 1min (~12 km), 270m
Backscatter/Depol: 10sec (~2 km), 30m

Profile Measurements:
- **Aerosol Extinction (532nm)**
- **Layer AOT, AOT at 532nm (from aircraft altitude)**
- **Aerosol/Cloud Backscatter (532,1064nm)**
- **Backscatter Color Ratio (1064/532nm)**
- **Lidar Ratio (extinction/backscatter) (532nm)**
- **Aerosol/Cloud Depolarization (532,1064nm)**
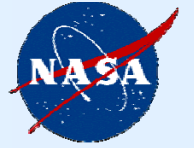- **Spectral Depolarization Ratio (1064/532nm)**
- **Mixed Layer Heights**

- AOT derived from DIAL/HSRL nadir data when DC-8 flew at or above 5 km

- AOT compared with AERONET level 2.0 AOT within 15 km, 30 min

- DIAL/HSRL AOT slightly lower than AERONET, possibly due to AOT not included above (> 5 km) or below (<150 m) profile

Slope = 0.93
Intercept = -0.0219
r = 0.94

DIAL/HSRL AOT (532 nm)

AERONET AOT (532 nm)
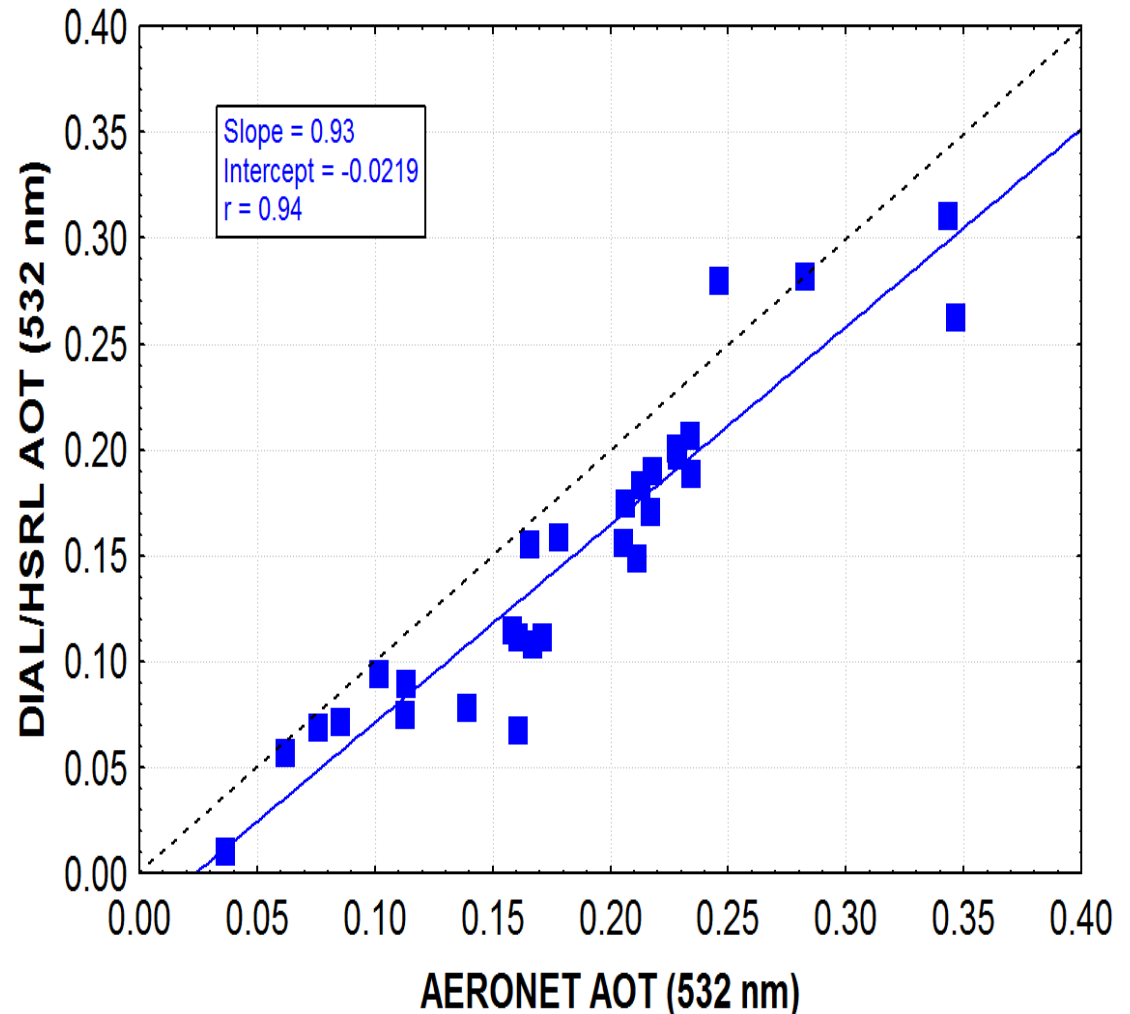
AERONET data – thanks to Brent Holben, Rick Wagener, Joe Shaw, Kevin Repasky, Kevin Knupp, Doug Moore

DIAL/HSRL Comparisons with GEOS-5 During SEAC4RS

GEOS-5 Atmospheric Data Assimilation System

- GEOS-5 Earth Modeling System, GOCART aerosol module
- Five non-interactive species - dust, sea salt, BC, OC, sulfate
- Convective and large scale wet removal
- Dry deposition and sedimentation
- Optics based on OPAC model (Nonspherical Dust) from Colarco; Kim
- Fire emissions – Quick Fire Emission Dataset (QFED)
  - Based on MODIS Fire Radiative Power
  - Emission factors tuned using MODIS AOT
  - Daily mean emissions
- Aerosol Data Assimilation
  - Terra/Aqua MODIS AOT
  - MISR AOT over bright surfaces
- Resolution
  - Horizontal: 25 km
  - Vertical: 72 layers
- PBL heights defined when diffusion coefficient falls below threshold
- **<u>GEOS-5 3-hourly results from SEAC4RS reanalysis are examined here</u>**
  (more info in Randles et al. talk A52A-05 Friday AM)

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dust	wind and topographic source, 5 mass bins
sea salt	wind driven source, 5 mass bins
black carbon	anthropogenic and wildfire source, mass hydrophic and hydrophilic
organic carbon	anthropogenic, biogenic, and wildfire source, mass hydrophic and hydrophilic
sulfate	anthropogenic and wildfire source of SO2, oxidation to SO4 mass
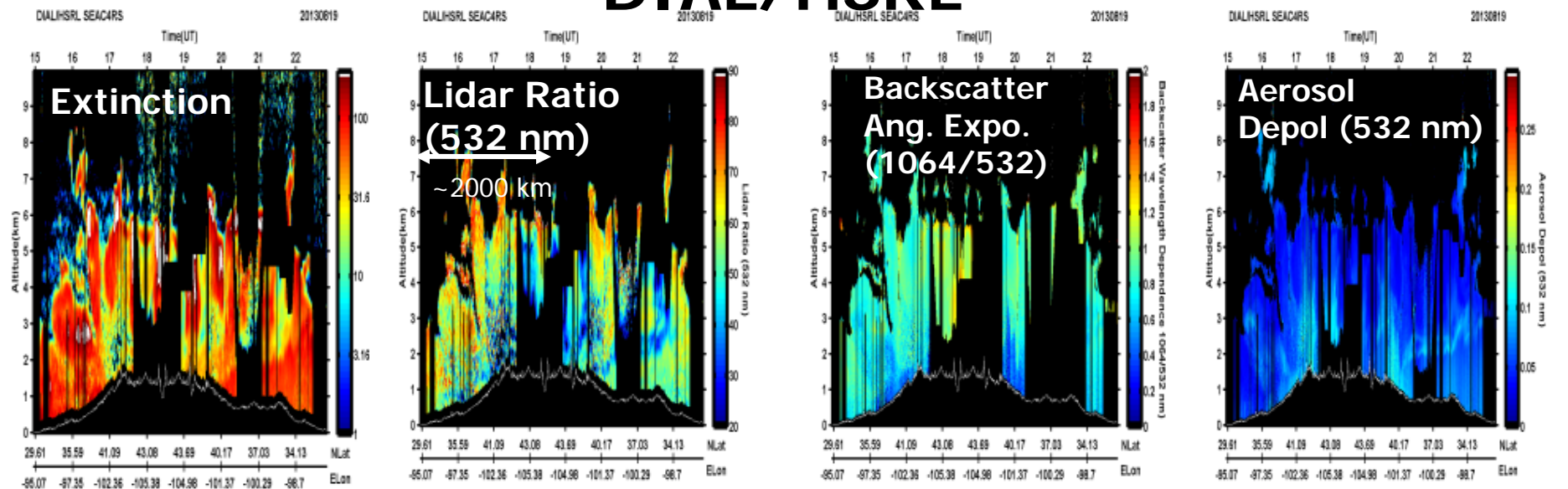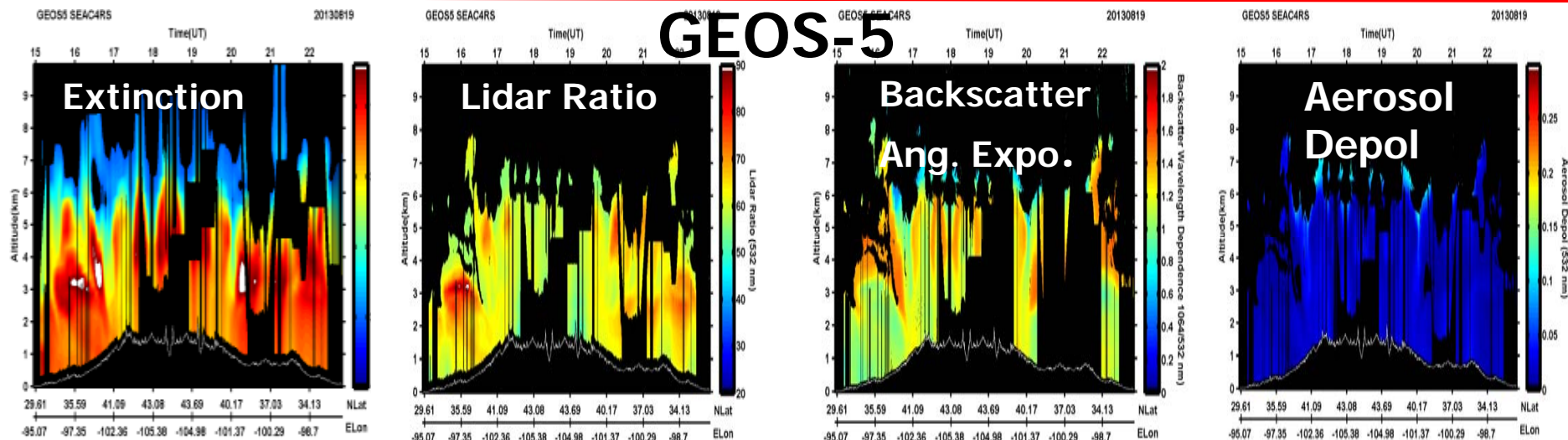
DIAL/HSRL

GEOS-5

DIAL/HSRL and GEOS-5 Median Backscatter and Extinction Profiles During SEAC4RS

GEOS-5 shows slightly higher backscatter and extinction in free troposphere
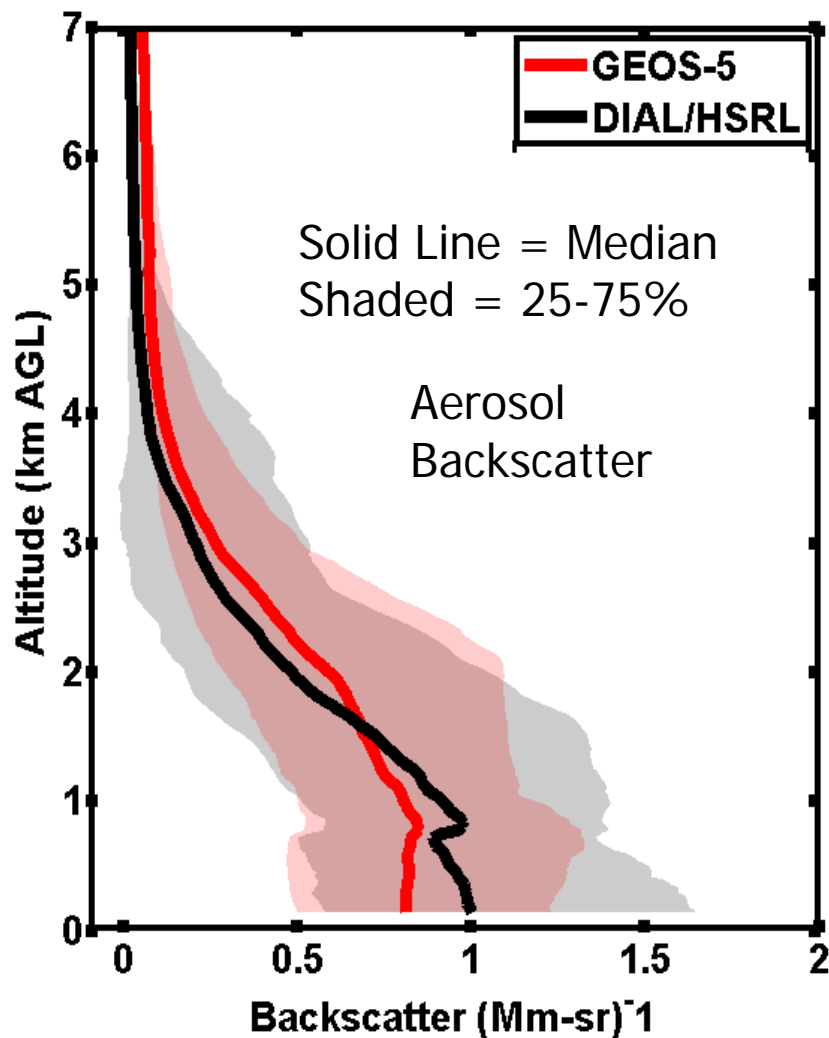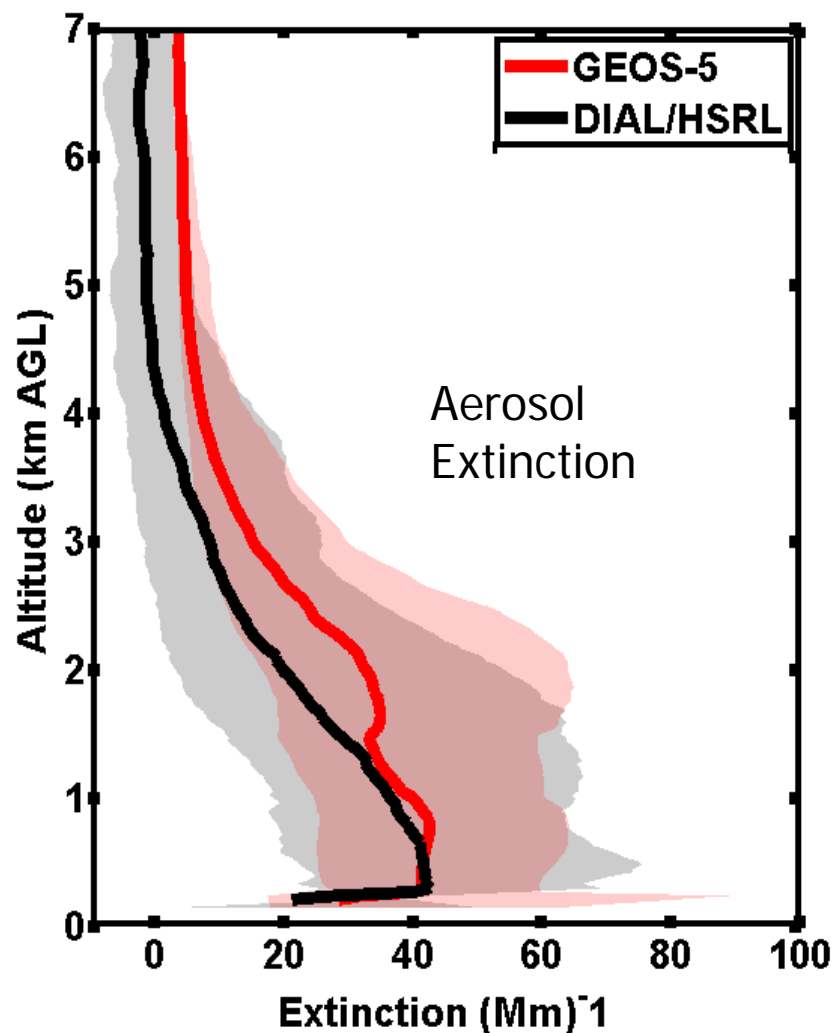
DIAL/HSRL and GEOS-5 Median Intensive Parameter Profiles During SEAC4RS

- Both DIAL/HSRL and GEOS-5 intensive parameters vary with altitude suggesting aerosol type varies with altitude
- Backscatter Angstrom exponent increasing with altitude suggests decreasing particle size with height
- GOES-5 lidar ratio higher than DIAL/HSRL
- DIAL/HSRL measured more nonspherical particles (i.e. dust) near the surface than represented by GEOS-5
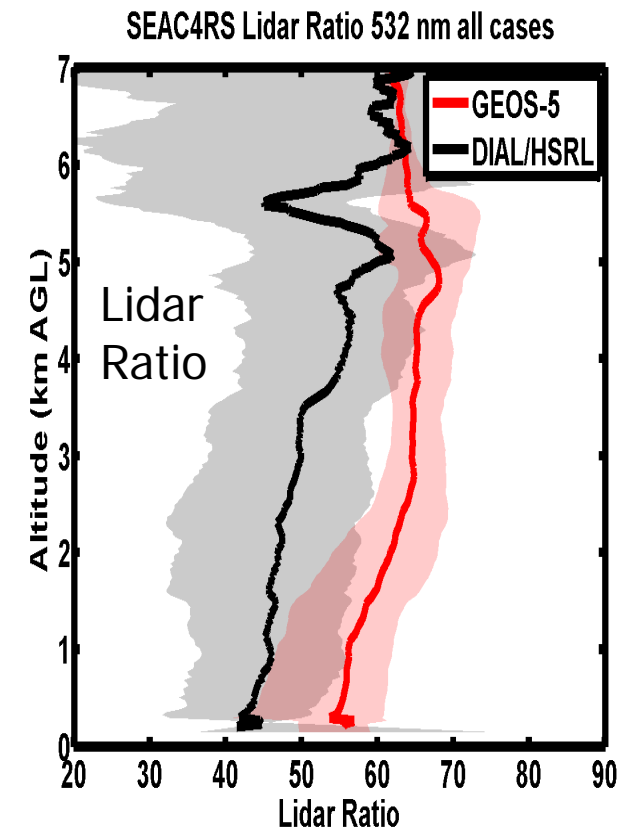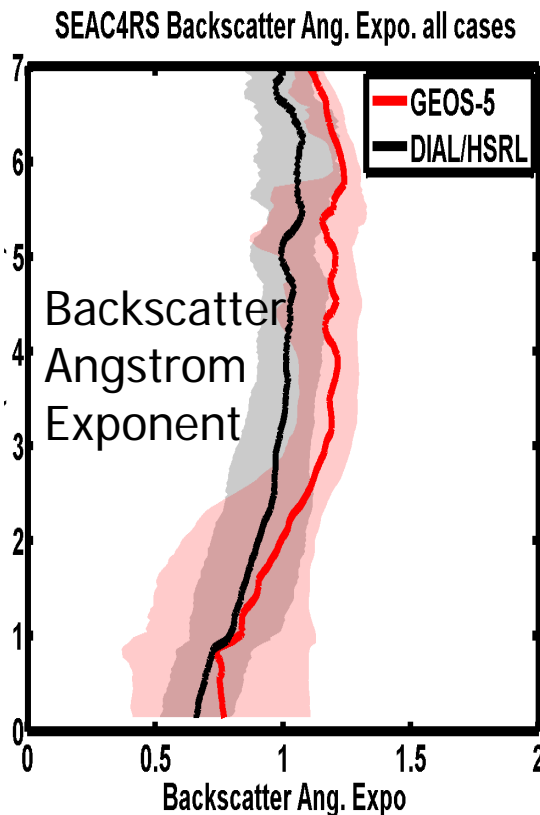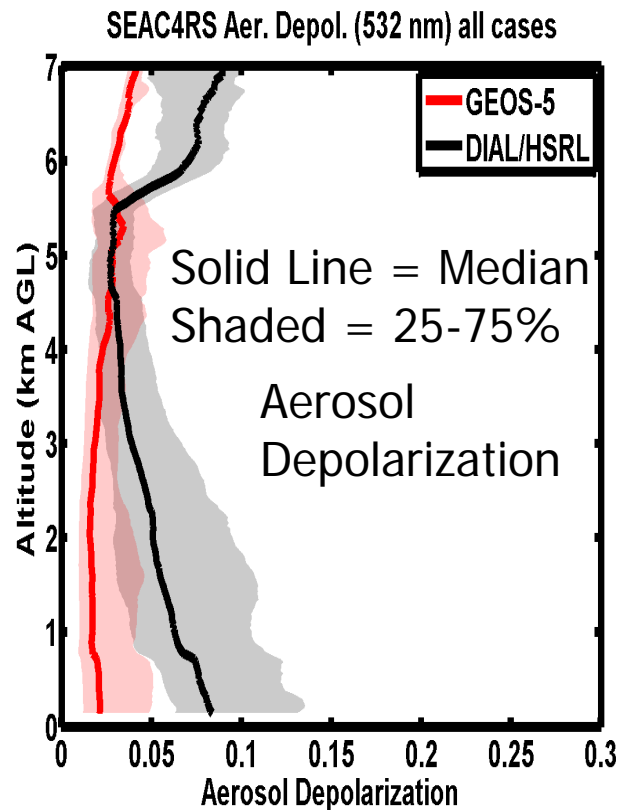
Comparisons of HSRL and GEOS-5 Boundary Layer Heights

Comparison of Boundary Layer Heights from HSRL-2 and GEOS-5 during DISCOVER-AQ

- HSRL-2 boundary layer heights from aerosol backscatter gradients
- GEOS-5 boundary layer heights from thermal diffusivity <u>and</u> aerosol backscatter gradients were about 450-500 m higher than those derived from HSRL-2 and DIAL/HSRL
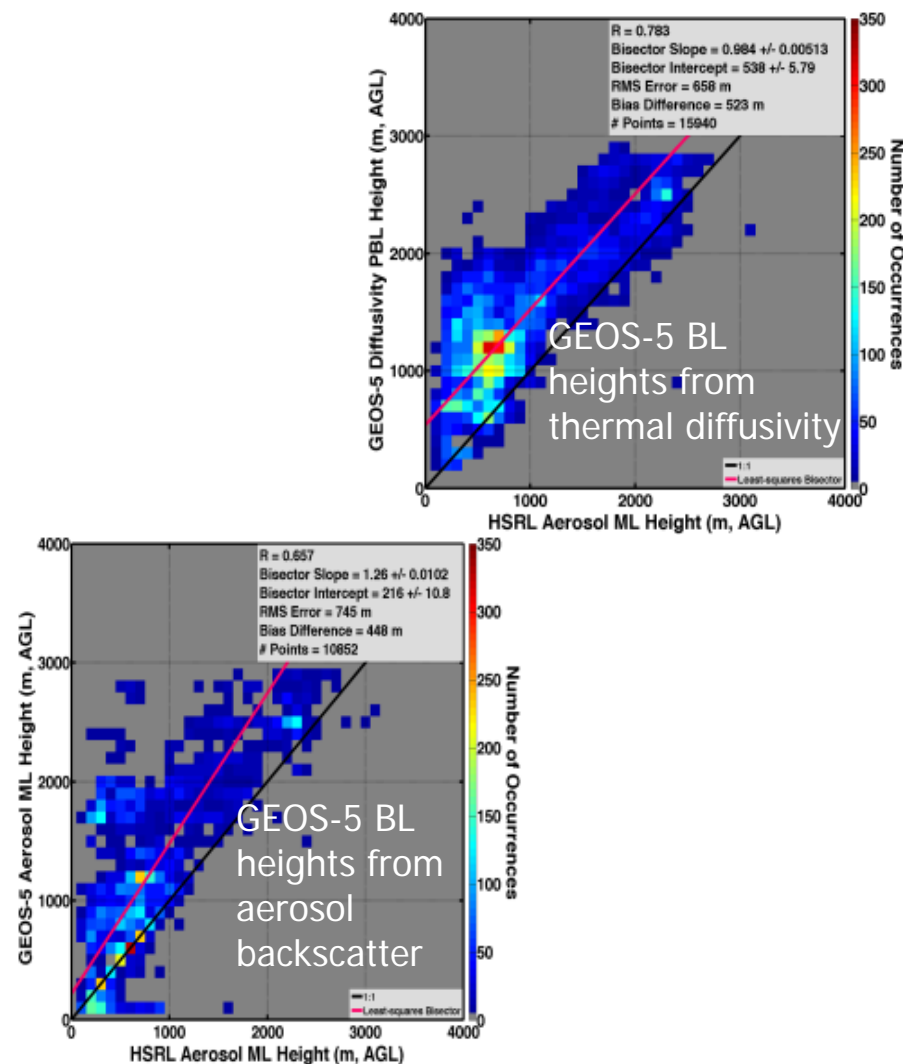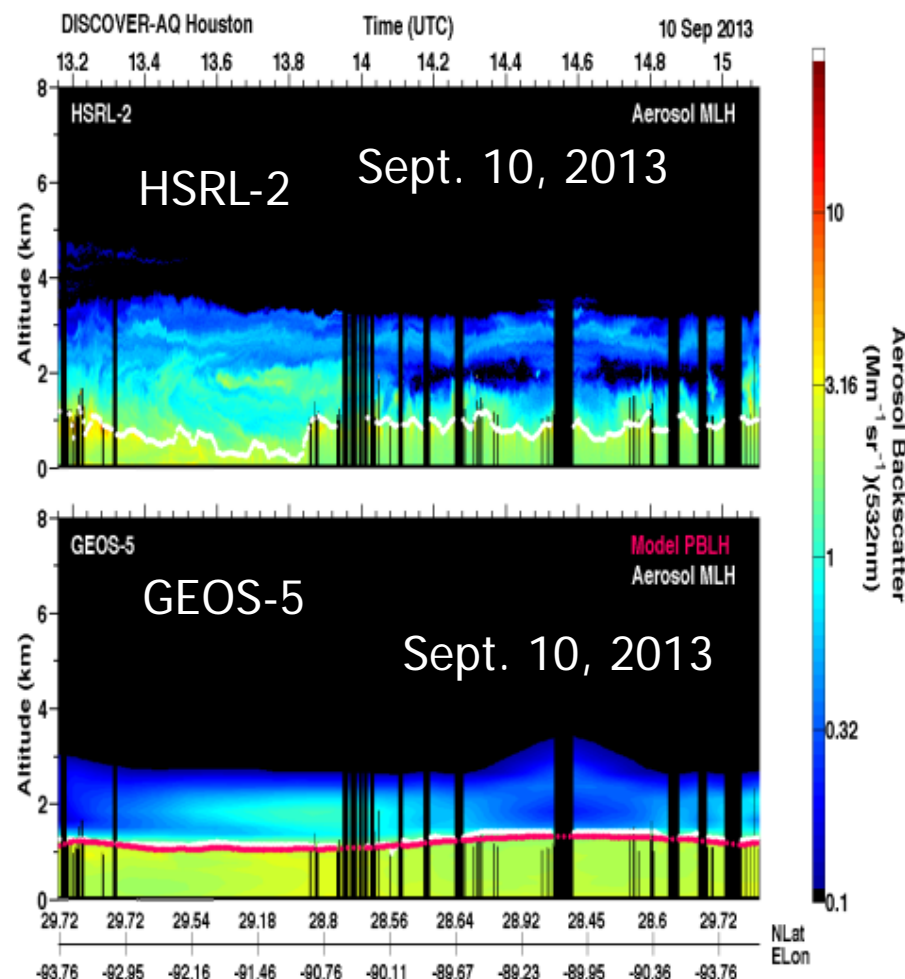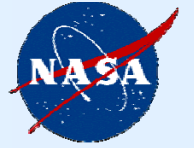

(see Scarino et al., poster A31C-3040 Wed. AM for more details)

Comparison of Boundary Layer Heights from HSRL-2 and GEOS-5 during SEAC4RS

- DIAL/HSRL boundary layer heights from aerosol backscatter gradients
- GEOS-5 boundary layer heights from thermal diffusivity <u>and</u> aerosol backscatter gradients were about 500-600 m higher than those derived from HSRL-2 and DIAL/HSRL
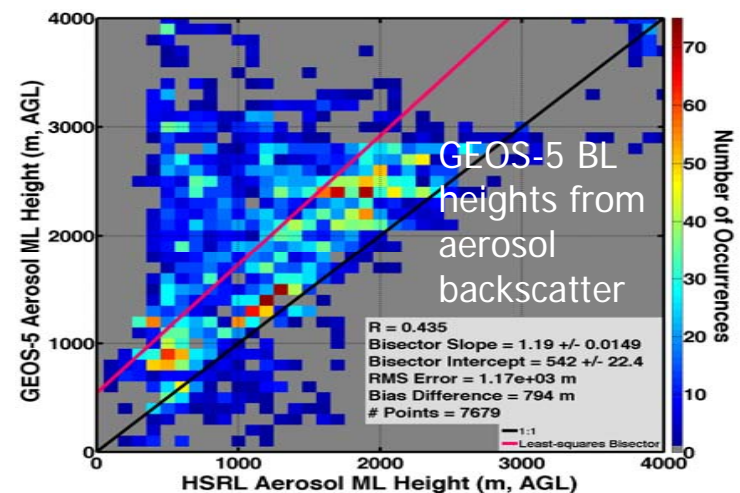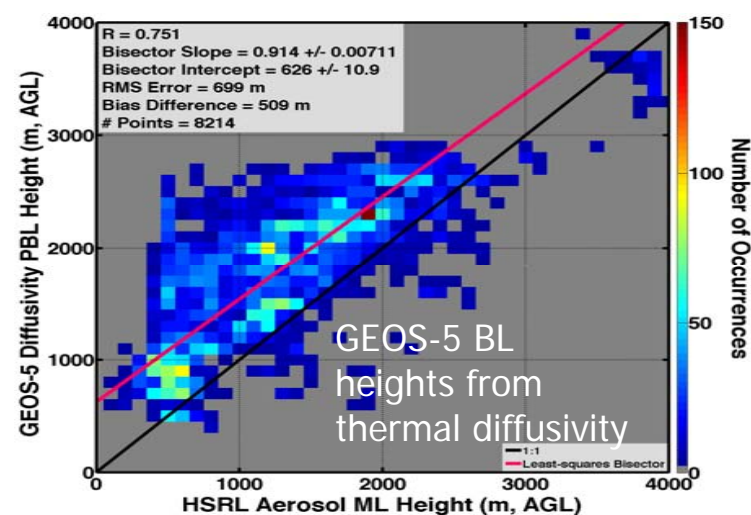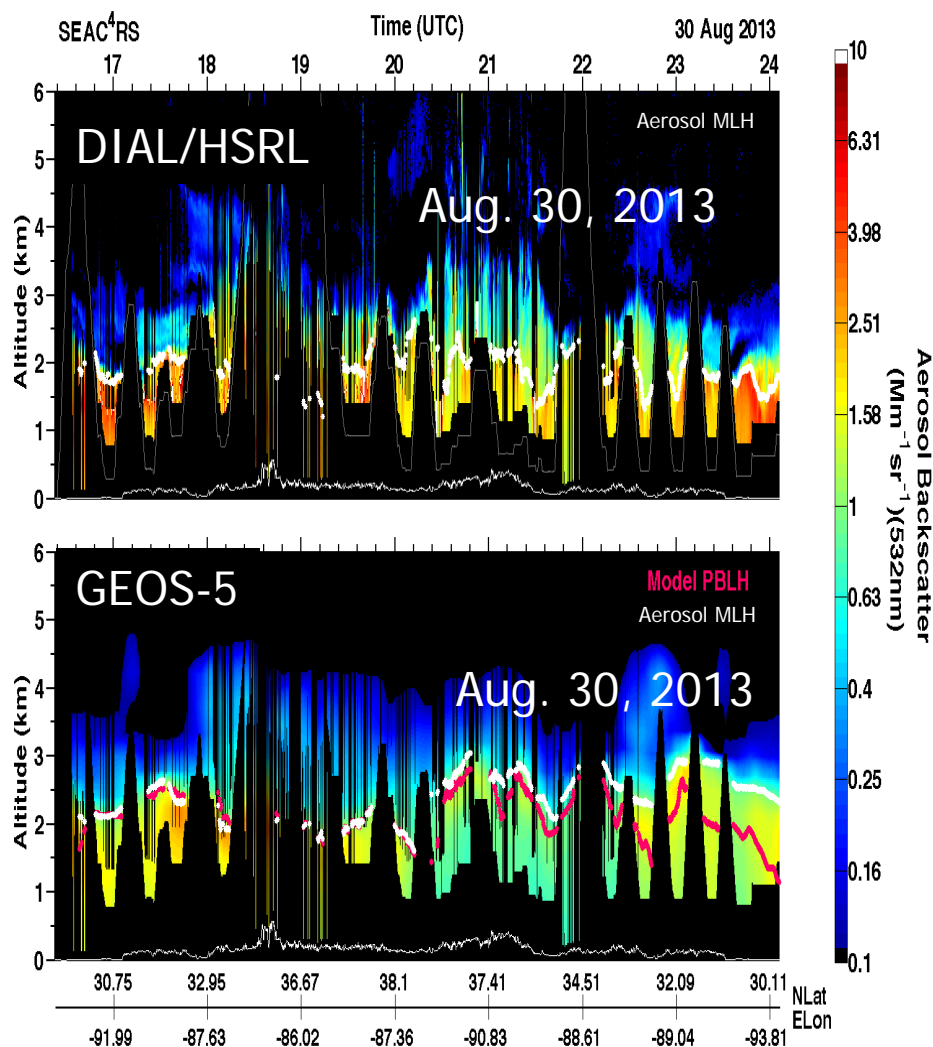
DIAL/HSRL Comparisons with ECMWF/MACC During SEAC4RS

ECMWF/MACC-II Model

- Monitoring Atmospheric Composition and Climate-Interim Implementation (MACC-II) Model
  - Provides information regarding air quality, global atmospheric composition, climate forcing, solar energy
  - Consumers include WMO, EPA and European Centers, weather services, solar irradiance forecast groups, field campaigns
- Aerosol model has components for dust, sea salt, organic matter, black carbon, sulfate
- Eleven prognostic aerosol variables and one for SO_2
- Aerosol sources taken from
  - Quick Fire Emission Dataset (QFED)
  - Speciated Particulate Emission Wizard (SPEW)
  - Emission Database for Global Atmospheric Research (EDGAR)
- Resolution
  - Horizontal: T255 (~80 km)
  - Vertical: 60 layers
- Aerosol Data Assimilation
  - Terra/Aqua MODIS AOT
  - Working towards assimilation of CALIOP aerosol profiles
- MACC-II 3-hourly results from reanalysis are examined here
- **SEAC4RS DIAL/HSRL data used to examine impacts of:**
  - **Assimilation of CALIOP data**
  - **Increased model resolution**
  - **Plume rise model impact on smoke injection heights**

Example: Comparison of Aerosol Extinction Profiles for August 19 Flight
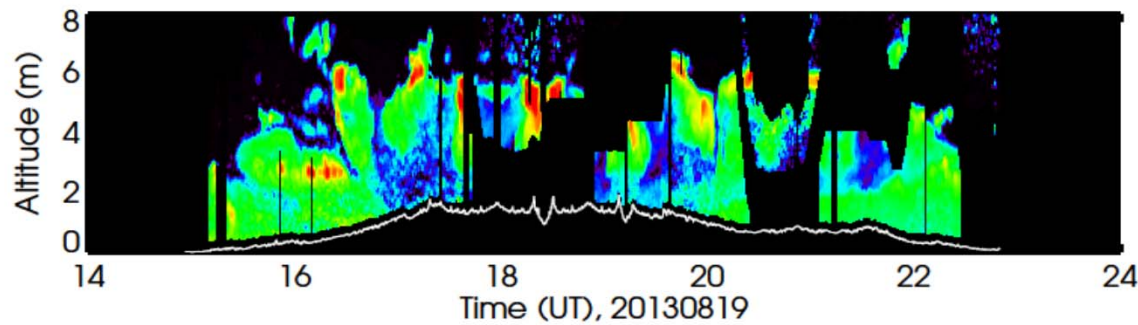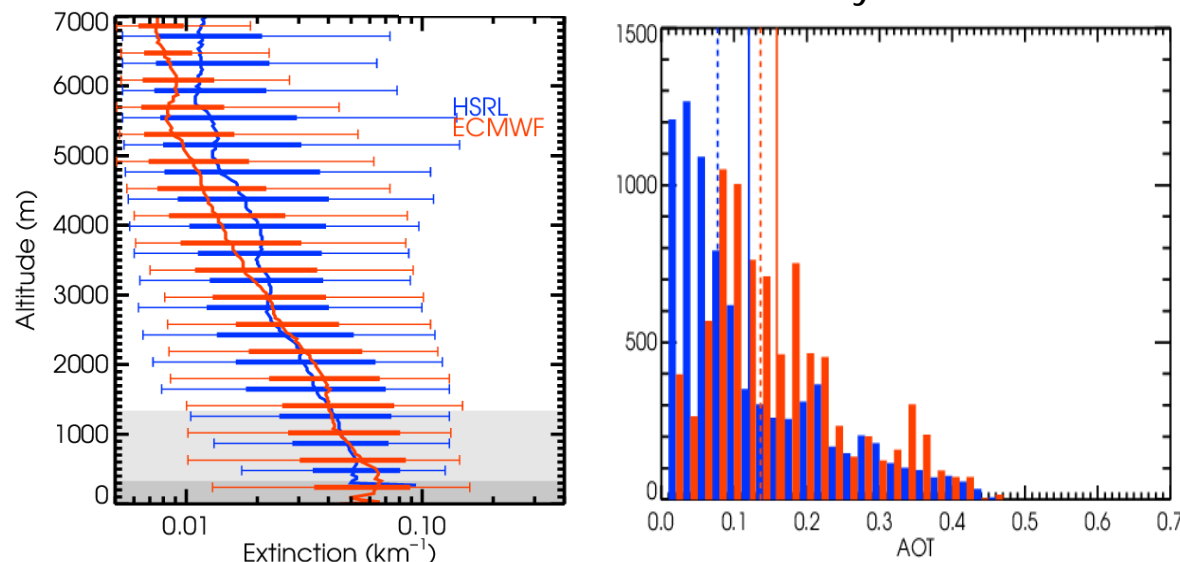

DIAL/HSRL
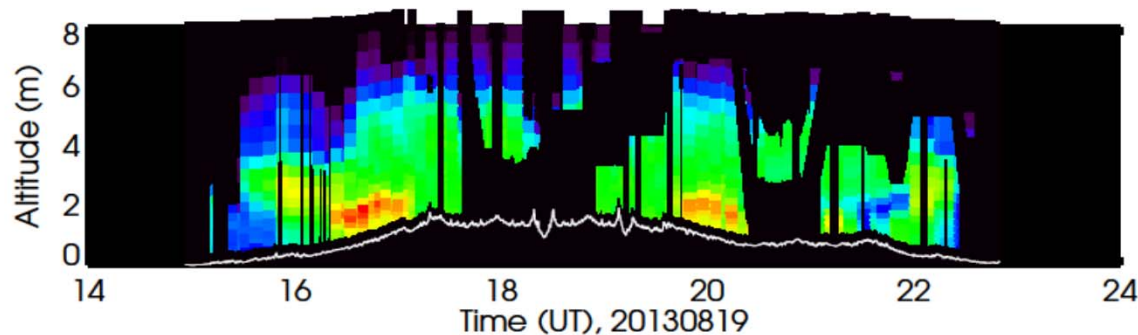
MACC-II
MODIS assimilation only
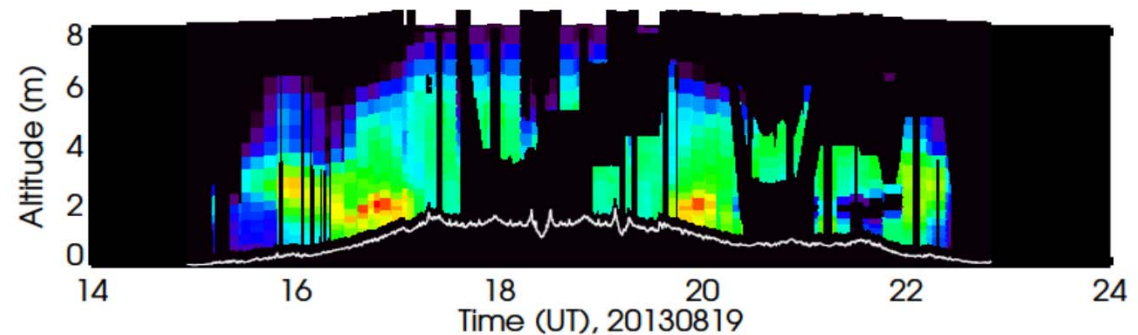
MACC-II
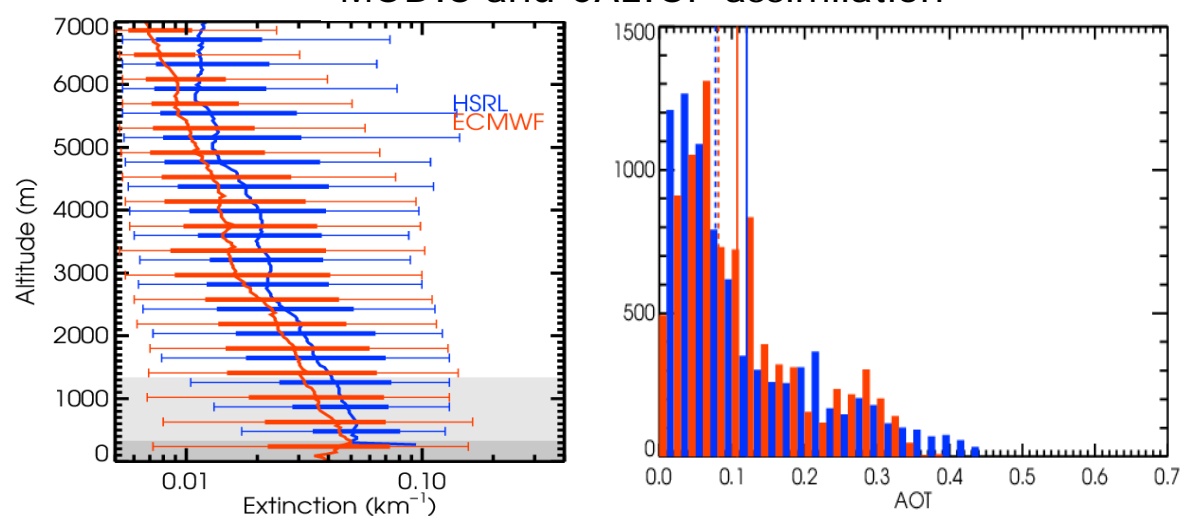MODIS and CALIOP
assimilation
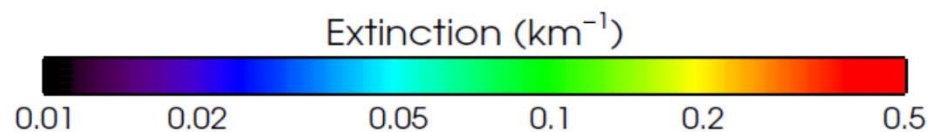
Comparison of Median Profiles with and without CALIOP assimilation
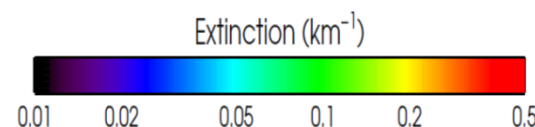
MODIS assimilation only

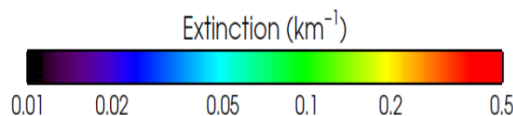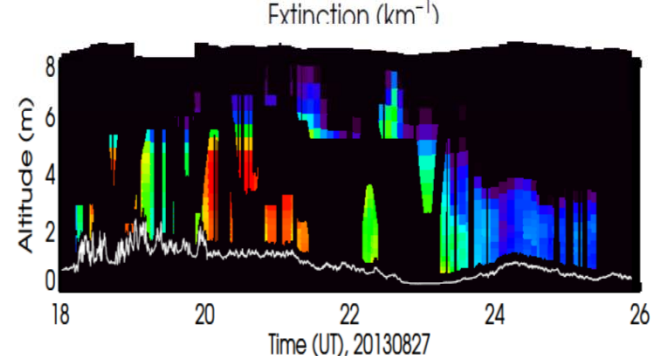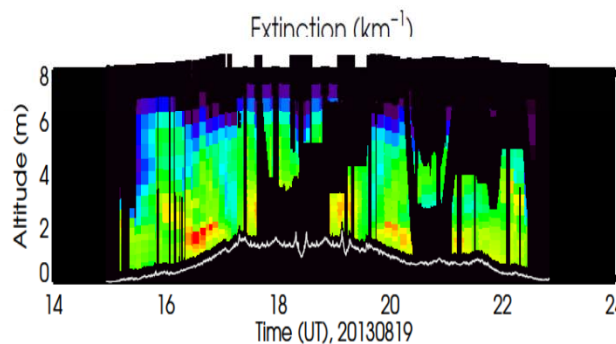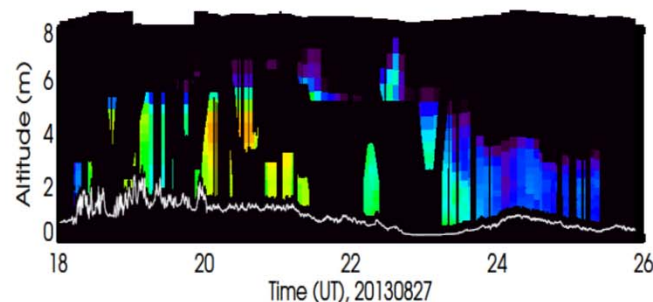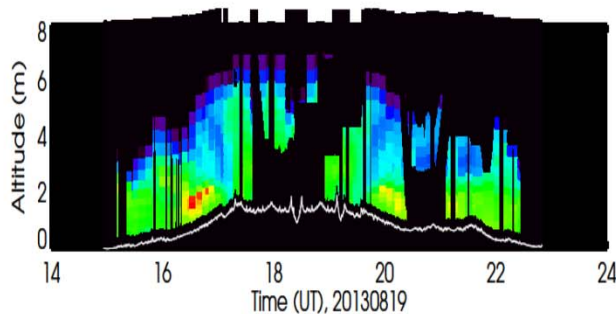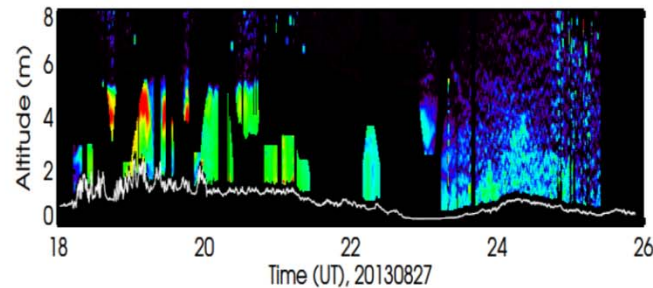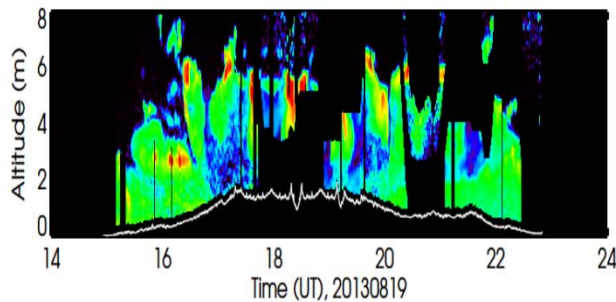MODIS and CALIOP assimilation

- Only small effects on median profiles
- Tend to lower the AOT with respect to runs that assimilate only MODIS AOT

# Impact of plume rise model smoke injection heights

- Injection heights for smoke emissions are estimated using Plume rise model (Paugam et al., 2015, in preparation, based on Freitas et al., 2007), and Sofiev's parameterization (Sofiev et al., 2012)

- This plume rise model uses MODIS FRP and modelled atmospheric profiles with a shallow convection scheme to represent detrainment from fire plume

- Initial comparisons show that both aerosol extinction and AOT increase throughout the profile, not necessarily at smoke height shown in DIAL/HSRL profile

Impact of MODIS assimilation
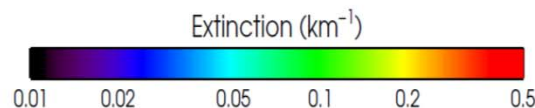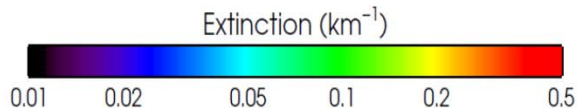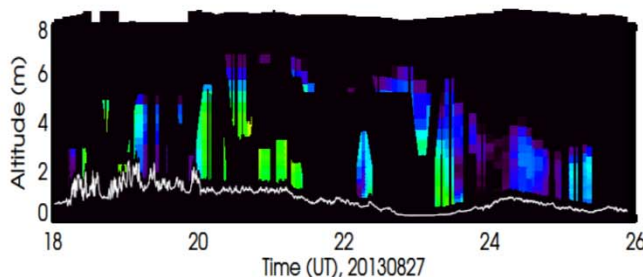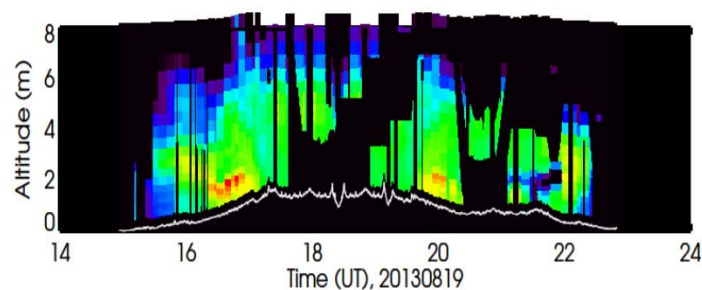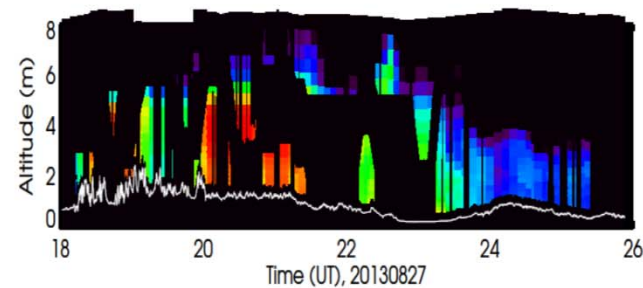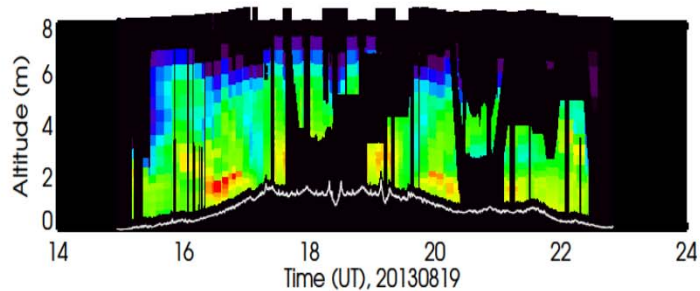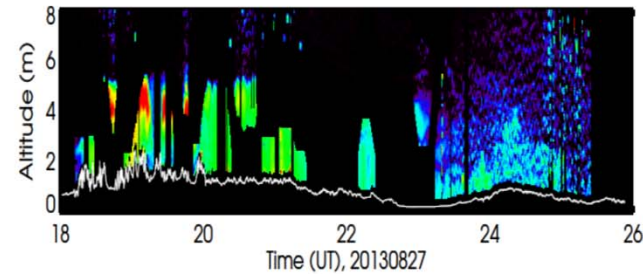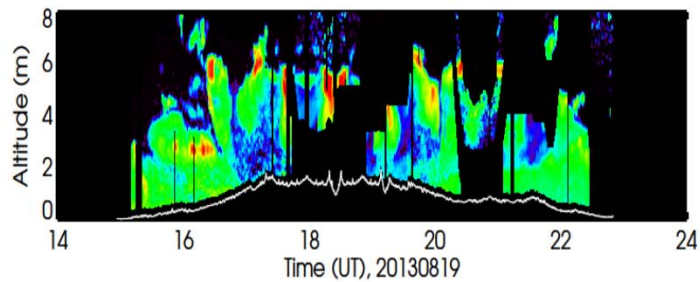
- Assimilation of MODIS AOT significantly reduces aerosol extinction profiles in some sections of these flights
- Reductions in aerosol extinction vary with altitude

Impact of Higher Model Resolution
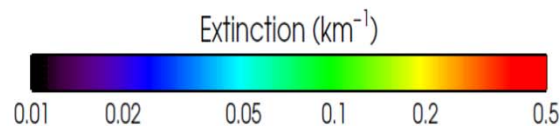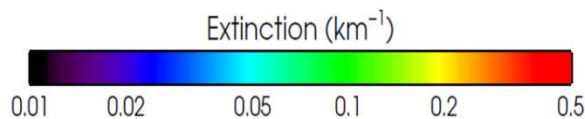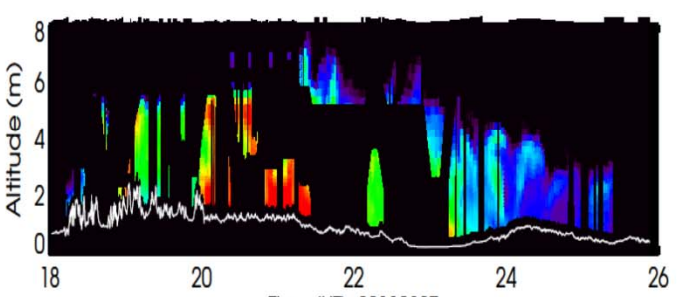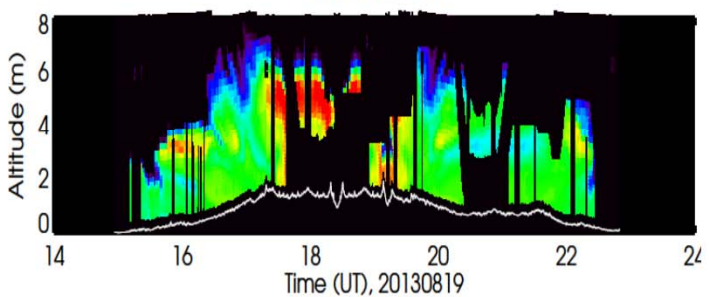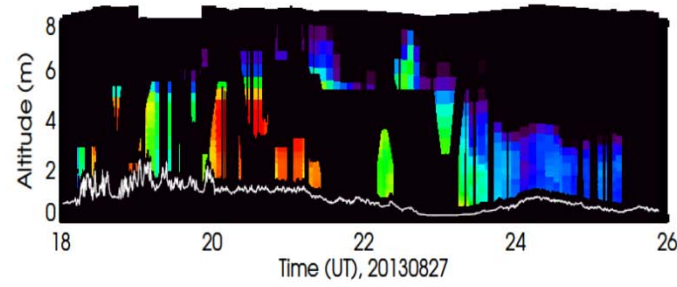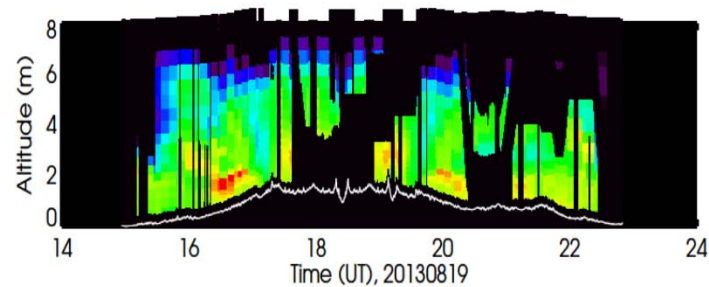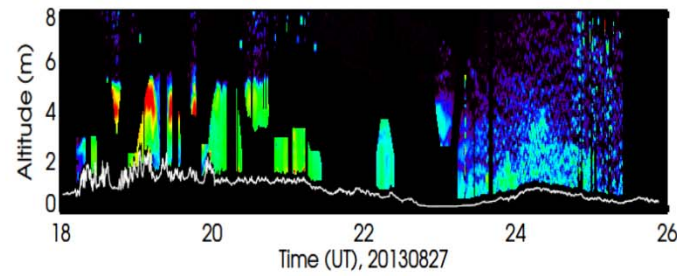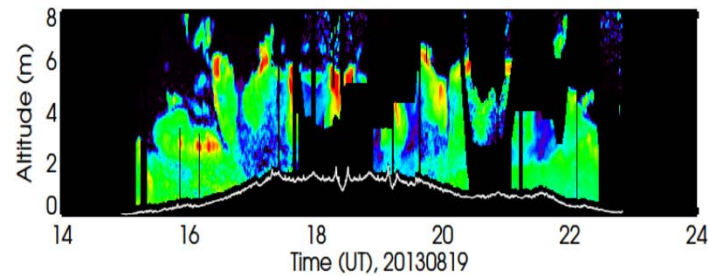
- Model resolution increased from T255 (80 km) to T1279 (16 km)

- Higher resolution seems to do better at representing smoke altitude than MODIS assimilation or plume rise model

Summary

➢ **HSRL measurements of aerosol <u>extensive</u> and <u>intensive</u> parameters provide additional constraints for developing and assessing models**

- On average, GEOS-5 profiles of aerosol extinction and backscatter are in good agreement with HSRL measurements

- GEOS-5 simulations of aerosol depolarization are biased low

- Both GEOS-5 and airborne HSRL data show aerosol intensive properties vary with altitude during SEAC4RS

- GEOS-5 Boundary layer heights during DISCOVER-AQ Houston are biased 500 m high relative to boundary layer heights derived from airborne lidar data

- Median ECMWF/MACC model extinction profile in agreement with median DIAL/HSRL profile

- Initial comparisons show increased model resolution does a better in representing smoke heights